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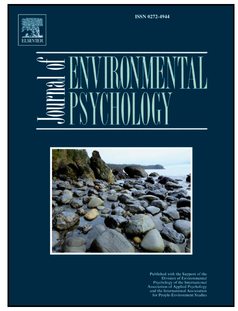

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Predictors of visual attention to climate change images: An eye-tracking study

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Abstract

Attentional engagement with climate change is an important precondition for intentional climate-friendly behavior. However, not much is known about the determinants of an individuals' implicit willingness to attend to this global problem. This study investigates two potentially relevant predictors of implicit attention to climate change: a) pro-environmental orientation as a trait factor and b) experimentally induced stress as a state factor. We expected positive effects of pro-environmental orientation and negative effects of stress.

Seventy-one male participants with either high or low pro-environmental orientation were randomly assigned to a stress or control condition. Afterwards, they viewed a series of climate change images and negative control images, which were presented simultaneously with positive and neutral distractors. Attentional deployment to the different stimulus categories was assessed using eye-tracking technology.

Participants with high pro-environmental orientation spent more time looking at climate change as well as other negative images, compared to participants with low pro-environmental orientation. This result suggests that pro-environmental individuals might be characterized by a general propensity to attend to negative information. Furthermore, stress reduced attentional deployment to both climate change and negative control images, which might indicate decreased interest in self-transcendent problems and/or increased efforts of emotion regulation under stress. In summary, these findings constitute first evidence for trait and state predictors of attentional engagement with climate change.

Keywords: climate change, eye-tracking, attention, stress, emotion regulation, Trier Social Stress Test

1. Introduction

Who attends to the climate change problem, and under which conditions? The current study aimed to contribute to these questions by examining how pro-environmental orientation and acute stress predict attention allocation to visual representations of climate change. Climate change constitutes a serious global problem that is largely driven by human behavior (IPCC, 2013). Mitigating climate change therefore requires behavioral change both at the policy level (reviewed in Bernauer, 2013) and at the individual level. Regarding the latter, one critical precondition for individuals to behave more climate-friendly is their awareness of and willingness to engage with the climate problem. In line with this, the failure to attend to global warming has been identified as one of several psychological barriers to behavior change (Gifford, 2011). In particular, Gifford argued that climate change often does not attract immediate attention because it is not causing immediate personal problems. Similarly, a recent review concluded that climate change is typically perceived as a non-urgent, abstract, and psychologically distant risk, which reduces people's engagement with this global issue (van der Linden, Maibach, & Leiserowitz, 2015).

Despite these observations of generally low public attention, not much is known about trait and state factors that might predict inter- and intra-individual differences in implicit attentional deployment to the climate change problem. The aim of the present study therefore was to investigate two potentially important determinants of individuals' willingness to attend to negative images of climate change (e.g., pictures of deforestation, droughts, floods, traffic). On the one hand, we examined the impact of relatively stable pre-existing inter-individual differences in pro-environmental orientation, since prior beliefs are likely to influence information selection in the sense of a cognitive filter (Bernauer & McGrath, 2016). On the other hand, attentional focus also critically depends on more transitory factors, such as the demands of the current situation and accompanying intra-personal states (e.g., prevailing moods and motivations). For these reasons, we studied the influence of experimentally induced acute stress, which constitutes a common state that is typically associated with substantial changes in mood and motivational priorities. We expected positive effects of pro-environmental orientation and negative effects of acute stress on selective attention to climate change images, as explained in more detail in the following paragraphs.

Regarding the influence of pro-environmental beliefs, one previous exploratory study reported an association between implicit attitudes towards low carbon footprint products and eye movements towards images of climate change (Beattie & McGuire, 2012). The study found that only participants with strong positive implicit attitudes towards low carbon footprint products focused more on climate change images compared to positive nature images. In the present study, we therefore compared the gaze behavior of subjects with high levels of pro-environmental attitudes and behaviors (high pro-environmental orientation; HP) to the gaze pattern of subjects with low pro-environmental orientation (LP). We expected HP participants to spend more time looking at climate change pictures compared to LP participants because of their stronger personal involvement with the issue. Importantly, however, increased attention of pro-environmental individuals to negative images might not be restricted to the topic of climate change and environmental destruction, but might reflect a more general propensity to attend to negative information. Pro-environmental individuals have been found to show higher levels of self-transcendent values (Nordlund & Garvill, 2002; Schultz et al., 2005), more prosocial values and behavior (Cameron, Brown, & Chapman, 1998; Kaiser & Byrka, 2011), and a stronger future orientation (Corral-Verdugo & Pinheiro, 2006; Ebreo & Vining, 2001), which might reflect an increased interest in problems that lie beyond immediate personal concerns. Furthermore, there is evidence that ecological values (Wiseman & Bogner, 2003) and environmental concern (Hirsh, 2010) are related to neuroticism, which, in turn, is associated with increased attention to negative or threatening information (reviewed in e.g., Mathews & MacLeod, 1994). To test for this possibility, we included negative control images (e.g., photographs of sad people) as explained below.

The second aim of the present research was to examine how attention allocation to climate change images is influenced by transient states of stress, which, at least in its more minor forms, is a common part of everyday life. We are not aware of any previous research on the potential effects of stress on the willingness to attend to representations of global warming or other environmental problems. However, a number of studies have reported a negative effect of stress on different types of prosocial behavior. One study found that social stress decreased the amount of money donated to a children's rights organization and diminished altruistic punishment behavior, reflecting an increase in material self-interest (Vinkers et al., 2013). Furthermore, cortisol response to a social stressor has been found to be positively associated with egoistic decision-making (Starcke, Polzer, Wolf, & Brand, 2011) and social exclusion has been shown to reduce various prosocial behaviors through a mechanism of reduced empathy (Twenge, Baumeister, DeWall, Ciarocco, & Bartels, 2007). Regarding pro-environmental behavior, we found in an earlier study that stress negatively affected actual climate-friendly behavior in that it reduced the amount of money donated to a climate protection foundation (Sollberger, Bernauer, & Ehlert, 2016). In line with this result, it has been theoretically argued that individuals might be more concerned about environmental destruction in situations where they are not occupied with more immediate personal concerns (Borden & Francis, 1978; Geller, 1995; Kollmuss & Agyeman, 2002). Acute stress constitutes such an immediate personal threat, which adaptively shifts the individual's focus to the present problem to enable a quick response, while problems that are not currently relevant are discounted (Buchanan & Preston, 2014). Stress would therefore be assumed to reduce the interest in or concern about climate change as a less immediate global problem.

Furthermore, stress might decrease implicit engagement with the climate change issue as a result of emotion regulation efforts. Empirically, this mechanism might not be easily distinguishable from the above proposed mechanism of reduced interest in not immediately relevant problems under stress. It would, however, be expected to influence attention to climate change pictures in the same direction. Specifically, stressed individuals might avoid attending to the climate problem in an attempt to evade further negative emotions that would be elicited by focusing on this global concern. This assumption is based on theoretical accounts that have proposed attentional deployment, i.e. selective attention towards or away from certain affective stimulus categories, as an important emotion regulation strategy (Gross, 2014; Koole, 2009; Todd, Cunningham, Anderson, & Thompson, 2012).

In accordance with this proposition, there is some empirical evidence for the avoidance of negative information in response to stress and negative mood states. Several studies have used reaction time or eye-tracking paradigms to examine how stress and mood influence attention allocation to negative as well as positive stimuli such as emotional pictures or words. One study found that acute stress and stress-induced mood decline were associated with avoidance of emotionally negative words in a reaction time task (Ellenbogen, Schwartzman, Stewart, & Walker, 2002). Using a similar paradigm, von Ceumern-Lindenstjerna et al. (2010) showed that current negative mood was accompanied by the avoidance of negative facial expressions in healthy subjects as well as subjects with various psychiatric disorders. Furthermore, older adults have been found to look away from negative facial expressions and towards happy faces following a sad mood induction (Isaacowitz, Toner, Goren, & Wilson, 2008). A similar effect was reported for young healthy participants who showed decreased visual attention to negative anxiety-related images and increased attention to positive images after induction of sad mood (Newman & Sears, 2015). Moreover, one study reported a significant association between negative mood and increased eye movements to happy faces after sad mood induction (Sanchez, Vazquez, Gomez, & Joormann, 2014).

Importantly, these findings are restricted to temporary induced states of stress and sad mood and do not apply to depression as a sustained condition of negative mood. Rather, depressed individuals have been found to show reversed attentional biases, that is, increased attentional deployment to negative information and/or reduced processing of positive information (Caseras, Garner, Bradley, & Mogg, 2007; Eizenman et al., 2003; Kellough, Beevers, Ellis, & Wells, 2008; Sears, Thomas, LeHuquet, & Johnson, 2010). Taken together, research on stress, mood, and visual attention suggests that avoidance of negative information as well as selective attention to positive information may serve as mechanisms of emotion regulation under conditions of stress and negative mood. While previous studies have focused on basic emotional stimuli such as facial expressions or social interactions, similar effects might also occur with more complex material representing a global social problem such as climate change.

In the present study, we used eye-tracking as a comparatively new method to assess attentional deployment in a naturalistic, unobtrusive, and continuous manner (Hermans, Vansteenwegen, & Eelen, 1999). A paradigm introduced by Eizenman et al. (2003) was employed, in which several complex visual stimuli competed for the subject's attention (see also Beattie & McGuire, 2012). More precisely, we examined to which extent participants devoted attention to climate change images when at the same time they had the opportunity to attend to positive nature images or neutral pictures. As outlined above, we hypothesized that pro-environmental orientation would increase, while acute stress would reduce selective attention to climate change pictures. We additionally included control trials which also featured negative, positive, and neutral images, but with no relation to climate change. These trials served the purpose of investigating a) how climate change images capture attention compared to other negative images presented under similar conditions, and b) whether potential effects of pro-environmental orientation and stress on attention to climate change images are topic-specific or rather generalize to other negative information.

2. Method

2.1 Participants

The data used for the research presented here were collected within a larger experimental study that investigated effects of acute stress and pro-environmental orientation on pro-environmental behavior. Apart from gaze behavior, the study also generated and analyzed data on climate-related donation behavior, the results of which are published elsewhere (Sollberger et al., 2016). The initial sample included 80 healthy male participants with either low (LP; *n* = 40) or high (HP; *n* = 40) pro-environmental orientation. To find eligible subjects, interested men were asked to complete a short online screening questionnaire, which assessed attitudes and behaviors related to energy conservation. Cut-off scores for low (lowest tertile) and high (highest tertile) pro-environmental orientation were determined based on a previous online survey (Sollberger, Bernauer, & Ehlert, 2015). Men who scored either below the lower cut-off or above the upper cut-off were invited to participate and assigned to the low and high pro-environmental groups, respectively. Participation was restricted to males due to the fact that the female cortisol stress response is considerably influenced by menstrual cycle phase and hormonal contraception – variables that would have been difficult to standardize in our experimental setting. For a more detailed description of the sampling procedure and further details on exclusion criteria and instructions related to the assessed endocrine parameters, see Sollberger et al. (2016). Baseline characteristics of the sample are reported in the empirical analysis below (section 3.1). All participants provided written informed consent and received 50 Swiss francs for their participation. The study protocol was approved by the local ethics committee of the Faculty of Arts, University of Zurich.

2.2 Procedure

Participants were individually tested in experimental sessions of approximately two hours. The timeline of the relevant parts of the experiment is presented in Figure 1. To control for the diurnal variation of cortisol secretion, all sessions started between 2 pm and 5 pm. LP and HP participants were randomly assigned to either the stress or control condition. In the stress condition, acute psychosocial stress was induced with the Trier Social Stress Test (TSST; Kirschbaum, Pirke, & Hellhammer, 1993), which has repeatedly been shown to elicit moderate to large psychological and physiological stress responses (Kirschbaum, 2010). The employed version of the TSST involved a 2-min introduction and a 5-min preparation and anticipation phase, followed by a 5-min public speaking task (mock job interview) and a 5-min mental arithmetic task (difficult subtraction). Both tasks were performed in front of an evaluation panel, consisting of one man and one woman in white lab coats, and a video camera.

In the control condition, a standardized placebo version of the TSST was employed (Het, Rohleder, Schoofs, Kirschbaum, & Wolf, 2009). As in the TSST, participants received instructions (2 min) and were given 5 min to prepare. Afterwards, they were left alone in an empty room to talk aloud about a movie, novel, or recent holiday trip for 5 min. Subsequently, participants were instructed to perform a simple arithmetic task, for which they were again left alone in the empty room for 5 min. There was no video camera in the room and it was explicitly stated that participants would not be observed or evaluated. This protocol does not elicit a cortisol response, since it successfully eliminates the social-evaluative threat and uncontrollability of the TSST while retaining all other important features (e.g., speaking aloud, orthostasis, task type) (Het et al., 2009).

Directly after completion of the TSST or its placebo version, all participants performed the eye-tracking task. After initial calibration of the eye-tracker, the 60 trials of the task were presented in two blocks of 30 trials, each lasting 8.5 min (see section 2.4).

Over the course of the experiment, salivary cortisol and mood state (see sections 2.5 and 2.6) were repeatedly assessed to verify the efficacy of the stress induction and to examine biological and psychological mechanisms of potential stress effects on gaze behavior. All participants were fully debriefed about the goal of the study and the nature of the stress test at the end of the experiment.

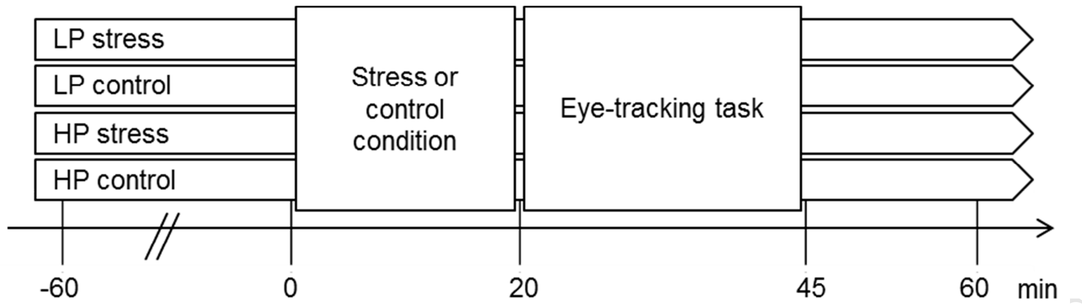

Figure 1. Design and procedure of the experiment. LP: low pro-environmental orientation; HP: high pro-environmental orientation.

2.3 Pro-environmental orientation

As described above, pro-environmental orientation was measured prior to study participation with four scales of a questionnaire on energy-related attitudes and behaviors (Sütterlin, Brunner, & Siegrist, 2011). Two scales assessed everyday energy-saving behavior in the household (12 items; e.g., "*Turn off standby on appliances*") and food domain (4 items; e.g., "*Avoid buying foods from distant countries*"). Subjects were asked to indicate how often they performed the described behaviors on a 6-point Likert scale (*1* = never, *6* = always). The remaining two scales measured personal norms regarding energy consumption (4 items; e.g., "*I feel personally obliged to avoid unnecessary energy consumption wherever possible*) as well as general energy-related attitudes (4 items; e.g., "*Energy conservation is important to me*"). Participants rated on a 6-point Likert scale how much each statement applied to them (*1* = not at all, *6* = completely). Higher scores represent higher levels of pro-environmental attitudes and behaviors. For details on how the LP and HP groups were selected, please refer to Sollberger et al. (2016).

2.4 Eye-tracking

2.4.1 Paradigm

The eye-tracking task included 60 trials, in which three images from three different categories were simultaneously shown on a gray background. The three pictures were presented with a size of 11.7° x 8.8° on a 22-inch screen (1680 x 1050 resolution), with a viewing distance of 70 cm. There were two different types of trials, 30 climate trials and 30 control trials. Each climate trial consisted of a negative climate change image, a positive nature image and a neutral image of an inanimate object (cf. Beattie & McGuire, 2012), while control trials included a negative control image, a positive control image, and a neutral image of an inanimate object. The three images were arranged in two different configurations as shown in Figure 2. Pictures from the three categories were randomly combined for each trial and participant, with the constraint that each image category appeared at each array position an equal number of times. Climate and control trials were presented in a random sequence. Each trial started with a fixation dot presented in the center of the screen for 2 s, followed by the presentation of the image array for 15 s. The open-source software OpenSesame (Mathôt, Schreij, & Theeuwes, 2011) was used for stimulus presentation and automatic control of the eye-tracker.

In line with previous studies (e.g., Hermans et al., 1999; Humphrey, Underwood, & Lambert, 2012; Kellough et al., 2008), subjects were informed that the eye-tracker assessed how their pupil dilation changed in response to different images (a secondary parameter, which is assessed by default by the eye-tracking system but was of no interest to the present hypotheses and thus not further analyzed). It was not mentioned that gaze direction was tracked in order to minimize demand effects. Participants were instructed to view the pictures in a natural way, as if they were watching television. The experimenter left the room during the presentation of the images.

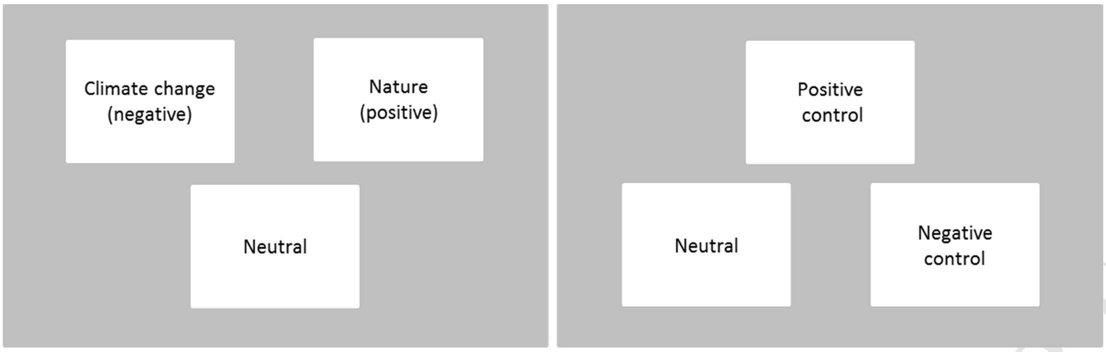

Figure 2. Two exemplary configurations of images for a climate trial (left) and a control trial (right) in the eye-tracking paradigm.

2.4.2 Stimuli

A total of 150 images from the following five categories were presented to each participant: climate change, nature, negative control, positive control, and neutral (30 images per category). Climate change images included photographs of causes and consequences of climate change, such as deforestation, traffic jams, smoking industrial chimneys, floods, droughts, oil spills, car exhaust, and landfills. Nature images depicted undisturbed natural scenery, such as forests, mountains, beaches, lakes, rivers, and hillsides. Negative and positive control images showed sad social scenes (e.g., crying mother and child) and happy social scenes (e.g., laughing men), respectively, while neutral images featured single inanimate objects (e.g., book, plate, lamp).

Neutral images as well as negative and positive control images were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008) and the EmoPics system (Wessa et al., 2010). For these picture systems, standardized affective norms are available, which describe subjects' emotional reaction to each picture in terms of valence and arousal. Climate change and nature images were chosen from publicly available online sources. A pilot study with a different male sample (N = 30, age: M = 25.2, SD = 5.5, range: 18-43) was conducted to find suitable images for the climate change and nature categories. The pilot sample rated a total of 114 climate- and nature-related images in terms of how strongly they associated each image with the climate change problem on a 9-point scale (*1* = not at all, *9* = very much). Furthermore, participants indicated their affective reaction to the pictures on the same scales as used for the IAPS and EmoPics affective norms. Specifically, the self-assessment manikin (SAM; Bradley & Lang, 1994) was administered to assess participants' response in terms of valence (*1* = unpleasant, *9* = pleasant) and arousal (*1* = calm, *9* = excited).

Thirty images that elicited strong associations with the climate change problem (M = 7.65, SD = 0.54) and, at the same time, obtained low valence ratings (M = 3.08, SD = 0.44) were chosen for the climate change category (arousal: M = 5.23, SD = 0.56). Thirty images with low climate change association ratings (M = 1.47, SD = 0.38) and high valence ratings (M = 6.93, SD = 0.38) were selected for the nature category (arousal: M = 2.58, SD = 0.38). Negative control images (valence: M = 2.96, SD = 0.46; arousal: M = 5.01, SD = 0.83) and positive control images (valence: M = 7.04, SD = 0.39; arousal: M = 4.44, SD = 0.49) were selected from the IAPS and EmoPics in such a way that their mean valence ratings were similar to those of the (negative) climate change and (positive) nature pictures, respectively. Climate and negative control images did not differ with regard to valence and arousal ratings (both ps ≥ .243). Similarly, the mean valence ratings for nature and positive control pictures were not significantly different from each other (p = .252). However, positive control images were rated as significantly more arousing than nature images ($t_{(58)}$ = -16.53, p < .001). Stimulus arousal level was therefore included as a covariate in the statistical analyses. For the neutral category, 30 pictures of inanimate objects with valence ratings around the scale center (4.5 – 5.5) were selected (valence: M = 4.95, SD = 0.18; arousal: M = 2.71, SD = 0.57). These images were used as the third image in both climate and control trials and were thus presented twice to each participant, while all other pictures were presented once. To control for habituation effects, stimulus repetition was also included as a covariate in the statistical analyses.

2.4.3 Eye-tracking system

Gaze data were recorded with an iView X RED system (SensoMotoric Instruments GmbH, SMI, Teltow, Germany). This video-based, dark pupil eye-tracking system assesses gaze direction based on the corneal reflection caused by an infrared light source. A 9-point calibration procedure was completed for each participant before the start of the picture viewing task, which enabled the eye-tracking system to develop the algorithm necessary to determine gaze direction. Calibration was repeated between the two blocks of trials if necessary. Over the course of the eye-tracking task, *x* and *y* coordinates of gaze position were measured with a sample rate of 60 Hz (one sample every 16.7 ms). Eye movement data were reduced with the SMI software BeGaze 3.6. Gaze that remained stable for more than 100 ms within 1° of visual angle was classified as a fixation. For each trial, three areas of interest (AOIs) were defined, which corresponded to the areas of the three presented images. The dependent variable was the fixation time per trial for each AOI in ms, resulting in a total of 12780 data points (fixation time for three images in each of 60 trials, for 71 participants; see section 2.7).

2.5 Cortisol

Salivary cortisol as an indicator of the endocrine stress response was assessed from five samples taken over the course of the experiment (cf. Figure 3a). Participants collected the first sample with a sampling device employing the passive drool method (SaliCaps, IBL International GmbH, Hamburg, Germany) because baseline testosterone was additionally determined from this sample and Salivettes have been reported to introduce bias into salivary sex steroid measurements (Celec & Ostatníková, 2012). The remaining samples were collected with Salivettes (Sarstedt, Nümbrecht, Germany) by chewing a cotton swab. Saliva samples were stored at -20 °C until biochemical analysis was performed. Cortisol was assessed with a standard luminescence immunoassay (IBL International GmbH, Hamburg, Germany). Intra- and inter-assay coefficients were both below 5%, with a sensitivity of 0.003 µg/dL.

2.6 Mood state

Participants assessed their current mood state at seven time points throughout the experiment (cf. Figure 3b) with the multidimensional mood questionnaire (MDMQ; Steyer, Schwenkmezger, Notz, & Eid, 1994). In the MDMQ, adjectives from the three mood dimensions *unpleasant-pleasant* (e.g., "unhappy" vs. "happy"), *restless-calm* (e.g., "nervous" vs. "relaxed") and *sleepy-awake*, (e.g., "tired" vs. "alert") are rated on a 5-point scale (*1* = not at all, *5* = very much). Higher scores indicate higher levels of pleasantness, calmness, and wakefulness.

2.7 Statistical analysis

Baseline parameters were compared between the four experimental groups (cf. Figure 1) using two-way analyses of variance (ANOVAs) with the between-subjects factors group (HP, LP) and condition (stress, control). To verify the effectiveness of the stress induction, cortisol and mood data were analyzed by means of mixed ANOVAs with the between-subjects factor condition (stress, control) and the within-subjects factor time (5 levels for cortisol, 7 levels for mood). The Greenhouse-Geisser correction was applied where appropriate.

To analyze the effects of pro-environmental orientation and stress on gaze direction, we conducted mixed-effects modeling with crossed random effects for subjects and stimuli (see Baayen, Davidson, & Bates, 2008). This approach takes into account the sampling of stimuli (i.e., that we used only a small sample of possible images) and allows for the analysis of gaze data on a trial-by-trial basis, enabling us to include covariates at the stimulus level (arousal of stimulus, stimulus repetition). In a first step, the full factorial design was tested for the dependent variable fixation time (ms), with the two between-subjects factors group (HP, LP) and condition (stress, control) and the two within-subjects factors topic of trial (climate, control) and valence of image (positive, negative, neutral). Income (mean-centered) was included as a covariate since it significantly differed between the four experimental groups (see section 3.1). Furthermore, stimulus arousal level (mean-centered) and stimulus repetition were included as covariates. All factors were effect-coded, so that the regression coefficients corresponded to main effects and interactions as in an ANOVA, with the intercept corresponding to the grand mean. This resulted in one contrast for factors with only two levels (condition: stress = 1, control = -1; group: HP = 1, LP = -1; topic: climate = 1; control = -1;

repetition: first presentation = -1, second presentation = 1). For the 3-level factor valence, two contrasts were specified: negative images vs. positive images (neg. = 1, pos. = -1, neut. = 0) and negative + positive images vs. neutral images (neg. = 1, pos. = 1, neut. = -2). A random intercept for subjects was included to model individual differences in gaze behavior between subjects, thus accounting for the repeated measurement. In addition, a random intercept for stimuli was included to account for differences in the selected images' propensity to capture attention. In a second step, separate models for the three different valences were computed to more specifically test our a priori hypotheses regarding effects of group and condition on negative images. Mixed modeling was performed in R (R Core Team, 2015) using the package *lme4* (Bates, Maechler, Bolker, Walker, & others, 2014). Coefficients were tested for significance with the package *lmerTest* (Kuznetsova, Brockhoff, & Christensen, 2015).

Furthermore, we examined whether cortisol response influenced attention allocation to the different stimulus categories by predicting fixation time based on cortisol response (AUCi: area under the curve with respect to increase; Pruessner, Kirschbaum, Meinlschmid, & Hellhammer, 2003), while controlling for income, arousal, repetition, and condition, and again including random intercepts for subjects and stimuli. In a second step, the interaction term of cortisol response and condition was entered into the models to examine whether cortisol response differentially affected gaze behavior in the stress compared to the control group.

Finally, to investigate whether gaze behavior influenced mood, we performed linear regression models with mood ratings after the eye-tracking task as the dependent variable. The following predictors were entered into the models in a first step: mood before the eye-tracking task, condition (stress, control), and attentional deployment indices (average fixation time for the different stimulus categories). In a second step, interaction terms between condition and attentional deployment indices were entered to test whether gaze behavior differentially affected mood in the stress compared to the control group.

The statistical analyses included 71 of the initial 80 participants. One participant was excluded because, due to a technical error, he was assigned to the LP control group even though he had scored in the intermediate tertile of pro-environmental orientation. Additionally, eight participants had to be excluded because of unstable eye-tracking (e.g., because of interference from eyelashes, droopy eyelids, or glasses). This resulted in 34 HP and 37 LP participants, with 36 participants assigned to the stress and 35 assigned to the control condition. Two participants (HP stress and LP stress) were excluded from the cortisol analyses due to extreme baseline values at the first assessment (more than 3 SDs above the sample mean; see e.g., Adam & Kumari, 2009; Kertes & van Dulmen, 2012). For one participant (LP stress), the experimenter forgot to administer the second saliva sample. This missing value was replaced with the mean of the participant's previous and subsequent samples.

3. Results

3.1 Baseline characteristics

The four experimental groups did not differ with regard to age, baseline cortisol, and baseline mood levels (see Table 1). However, there was an unintended significant condition effect for annual income (F (1,67) = 7.79, p = .007, η_p^2 = .10), reflecting that participants assigned to the placebo condition had a significantly higher income than participants in the stress condition. Since income as an indicator of socioeconomic status might influence gaze behavior, it was included as a covariate. For example, low income can constitute a chronic stressor and thus might reduce interest in self-transcendent problems such as climate change. Furthermore, socioeconomic status has been found to be positively associated with nonverbal social disengagement from others (see e.g., Kraus and Keltner, 2009), which might affect gaze behavior with regard to social scenes.

Table 1. Baseline parameters for the four experimental groups.

	HP Stress (n = 18)	HP Control (n = 19)	LP Stress (n = 18)	LP Control (n = 16)	Group effect F	Condition effect F	Group x Condition interaction F
Age	26.6 (6.3)	28.2 (6.8)	26.7 (4.1)	29.3 (5.2)	0.16	2.36	0.13
Annual income category	1.9 (0.8)	2.3 (0.8)	1.8 (0.7)	2.6 (1.1)	0.54	7.79**	1.00
Cortisol (nmol/l)[a]	10.2 (4.3)	9.1 (3.2)	10.2 (3.8)	8.1 (3.8)	0.23	3.08	0.28
MDMQ pleasantness[a]	4.1 (0.6)	4.5 (0.4)	4.2 (0.7)	4.2 (0.9)	0.38	1.82	1.90
MDMQ calmness[a]	3.8 (0.8)	4.2 (0.7)	4.2 (0.6)	4.4 (0.6)	3.11	3.57	0.23
MDMQ wakefulness[a]	3.2 (0.8)	3.6 (0.7)	3.6 (0.8)	3.4 (1.0)	0.42	0.45	2.19

Values represent means (standard deviations). HP: high pro-environmental orientation; LP: low pro-environmental orientation. [a]Baseline measurements (before stress/control condition). **p < .01

3.2 Stress response

The stress condition successfully induced a cortisol response, as indicated by a significant interaction effect of the factors condition and time in a two-way mixed ANOVA (F (1.93, 129.48) = 29.68, p < .001, η_p^2 = .31). Specifically, salivary cortisol strongly increased in response to the TSST (see Figure 3a). Planned comparisons revealed that the stress groups showed higher cortisol levels than the control groups immediately after the TSST as well as 15 and 45 min. later (all ps < .001). In addition, the stress condition impaired participants' self-reported mood, as evidenced by significant condition x time interaction effects for the MDMQ scales pleasantness (F (4.47, 303.87) = 7.41, p < .001, η_p^2 = .10) and calmness (F (6, 408) = 11.10, p < .001, η_p^2 = .14). Planned comparisons indicated that pleasantness and calmness ratings were significantly lower in the stress compared to the control groups directly after the TSST (ps < .001) as well as 15 min later (ps < .05; see Figure 3b). The

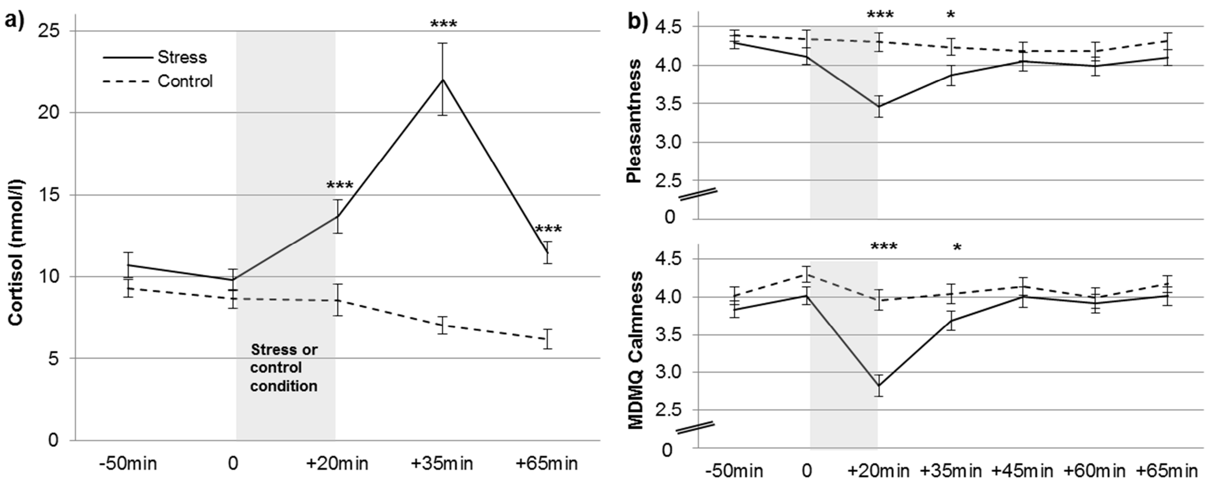

Figure 3. Salivary cortisol (a) and mood ratings (b) over the course of the experiment in the stress and control conditions. Error bars indicate standard errors of the mean. *p < .05; ***p < .001; MDMQ: multidimensional mood questionnaire.

MDMQ wakefulness dimension was not differentially affected by the stress and control conditions (p = .36).

3.3 Gaze behavior

3.3.1 Effects of stress and pro-environmental orientation on gaze behavior

Fixation time was analyzed by fitting a mixed model with fixed effects for condition, group, topic of trial, valence of image, and all interaction effects, the covariates income, arousal, and repetition, and random intercepts for subjects and stimuli. The model results (shown in Table 2) revealed significant main effects of topic, image valence (neg. + pos. vs. neut.), stimulus arousal, and stimulus repetition on fixation time. Furthermore, there were significant interaction effects of valence (neg. vs. pos.) and condition, valence (both contrasts) and group as well as valence (neg. vs. pos.), condition, and group. To elucidate these interactions with valence and to more specifically test our hypotheses, we computed separate models for negative, positive, and neutral pictures, including fixed effects for topic of trial, condition, group, and their interactions, the covariates income, arousal, and repetition (for the neutral image model), and random intercepts for subjects and stimuli (see Table 3).

The model for negative images revealed significant main effects of condition, group, topic, and arousal (ps < .05, Table 3), but no interaction effects. The effect of condition was due to reduced fixation time on negative images in the stress compared to the control condition (Figure 4a), irrespective of participants' pro-environmental orientation and the topic of the picture (climate change vs. negative control). The group effect indicated that HP participants spent more time fixating on negative pictures than LP participants (Figure 4b), again regardless of the topic of the negative picture. The main effect of topic reflected increased fixation time on negative climate change images compared to negative control images (Figure 4c).

In the model for positive images, only the effect of arousal was significant (p < .01, Table 3), indicating that fixation time on positive pictures was not influenced by topic, condition or group.

The model for neutral images revealed significant effects of topic ($p < .001$, Table 3) and arousal ($p < .05$), and repetition ($p < .001$). The effect of topic reflected that participants spent more time fixating on neutral pictures in climate compared to control trials (Figure 4c). Furthermore, there was a significant interaction effect of condition and topic ($p < .05$, Table 3), which indicated that stress negatively affected viewing time of neutral pictures in control but not in climate trials (not shown).

Table 2. Mixed model predicting fixation time (ms). Effects in bold font are significant ($p < .05$).

Fixed effects	Estimate	*SE*	*t*
Intercept	**3209.88**	**84.63**	**37.93**
Topic	**100.68**	**37.43**	**2.69**
Valence neg. vs. pos.	-139.63	72.63	-1.92
Valence neg. + pos. vs. neut.	**418.45**	**50.54**	**8.28**
Condition	-133.7	76.96	-1.74
Group	104.28	73.14	1.43
Income	-134.08	85.19	-1.57
Arousal	**486.02**	**70.07**	**6.94**
Repetition	**-385.51**	**30.48**	**-12.65**
Topic x Valence neg. vs. pos.	96.55	58.42	1.65
Topic x Valence neg. + pos. vs. neut.	-12.41	20.69	-0.6
Topic x Condition	23.88	17.63	1.35
Valence neg. vs. pos. x Condition	**-85.78**	**21.59**	**-3.97**
Valence neg. + pos. vs. neut. x Condition	-18.09	12.46	-1.45
Topic x Group	-12.14	17.63	-0.69
Valence neg. vs. pos. x Group	**128.43**	**21.59**	**5.95**
Valence neg. + pos. vs. neut. x Group	**59.1**	**12.46**	**4.74**
Condition x Group	-27.7	73.39	-0.38
Topic x Valence neg. vs. pos. x Condition	18.12	21.59	0.84
Topic x Valence neg. + pos. vs. neut. x Condition	-10.79	12.46	-0.87
Topic x Valence neg. vs. pos. x Group	-29.61	21.59	-1.37
Topic x Valence neg. + pos. vs. neut. x Group	-21.17	12.46	-1.7
Topic x Condition x Group	-19.12	17.63	-1.08
Valence neg. vs. pos. x Condition x Group	**-83.32**	**21.59**	**-3.86**
Valence neg. + pos. vs. neut. x Condition x Group	-4.31	12.46	-0.35
Topic x Valence neg. vs. pos. x Condition x Group	6.6	21.59	0.31
Topic x Valence neg. + pos. vs. neut. x Condition x Group	9.51	12.46	0.76

Random effects	Variance
Residual	3954515
Subject (Intercept)	353323
Stimulus (Intercept)	194556

Table 3. Mixed models predicting fixation time (ms) separately for negative, positive and neutral images. Effects in bold font are significant (p < .05).

	Negative images			*Positive images*			*Neutral images*		
Fixed effects	Estimate	*SE*	*t*	Estimate	*SE*	*t*	*Estimate*	*SE*	*t*
Intercept	**4526.63**	**144.81**	**31.26**	**4018.86**	**117.62**	**34.17**	**1855.2**	**87.3**	**21.26**
Group	**280.54**	**126.71**	**2.21**	48.22	106.76	0.45	-15.9	75.2	-0.21
Condition	**-280.46**	**133.34**	**-2.10**	-15.52	112.35	-0.14	-105.1	79.1	-1.33
Topic	**172.73**	**79.02**	**2.19**	-26.05	142.36	-0.18	**125.5**	**21.5**	**5.84**
Income	-281.26	147.59	-1.91	39.15	124.36	0.31	-160.1	87.6	-1.83
Arousal	**597.7**	**111.84**	**5.34**	**466.93**	**138.86**	**3.36**	**200.6**	**88.1**	**2.28**
Repetition	-	-	-	-	-	-	**-385.5**	**21.5**	**-17.97**
Group x Condition	-99.97	127.15	-0.79	33.23	107.13	0.31	-16.4	75.5	-0.22
Group x Topic	-62.92	32.56	-1.93	-3.7	32.05	-0.12	30.2	21.5	1.41
Condition x Topic	31.2	32.56	0.96	-5.03	32.05	-0.16	**45.5**	**21.5**	**2.12**
Group x Condition x Topic	-3.01	32.56	-0.09	-16.21	32.05	-0.51	-38.1	21.5	-1.78
Random effects	Variance			Variance			Variance		
Residual	4499340			4358285			1957850		
Subject (Intercept)	1051494			727056			364252		
Stimulus (Intercept)	302243			151479			60008		

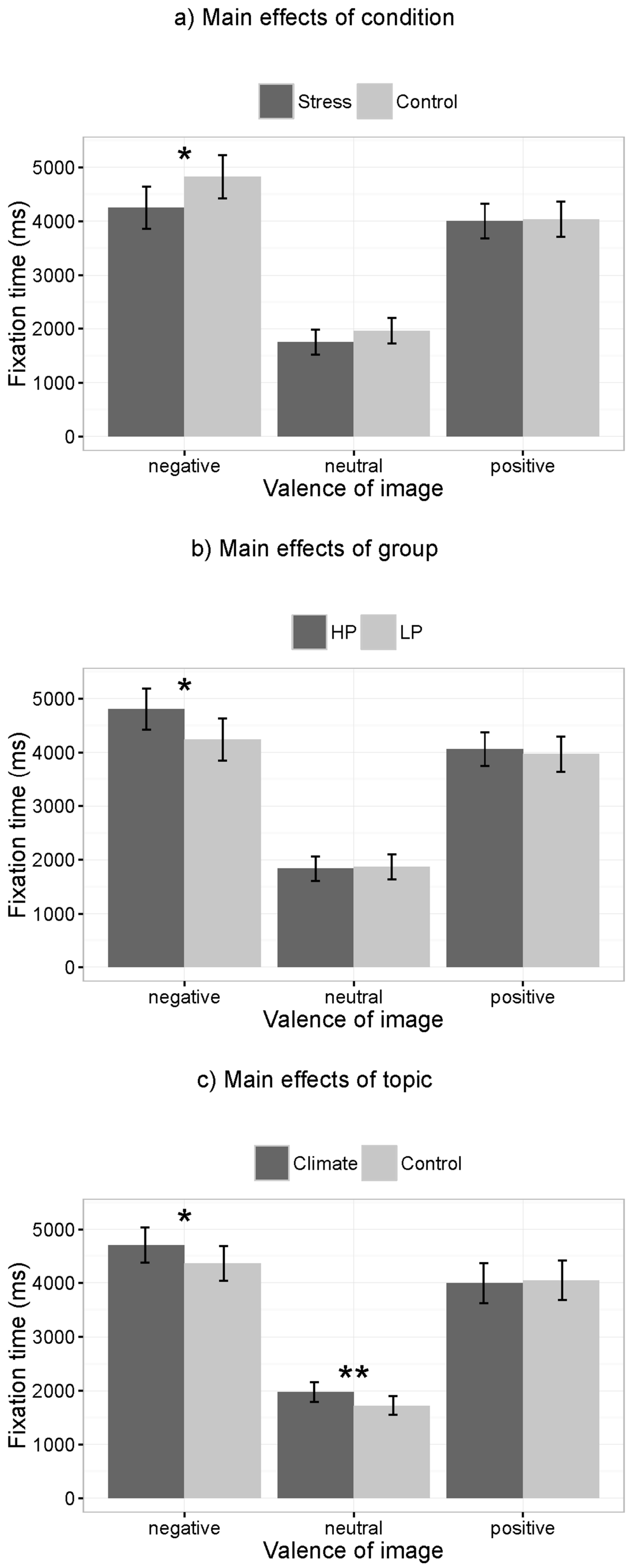

Figure 4. Model predictions for the main effects of a) condition, b) group, and c) topic on fixation time for negative, neutral, and positive pictures. Error bars represent 95% confidence intervals. HP: high pro-environmental orientation, LP: low pro-environmental orientation. **p* < .05, ***p* < .01, ****p* < .001.

3.3.2 Correlates of gaze behavior

We additionally examined whether the cortisol response was predictive of attention to negative, positive, and neutral pictures. Mixed models controlling for income, arousal, repetition, and condition revealed that cortisol response did not significantly predict average fixation time for negative, positive, and neutral images (all *p*s ≥ .13). Moreover, there were no significant interaction effects of condition and cortisol response on attentional deployment (all *p*s ≥ .38).

We also tested whether gaze behavior was predictive of mood changes. Regression analyses yielded no significant effects of average fixation time for negative, positive, and neutral images on pleasantness or calmness ratings after the eye-tracking task (all *p*s ≥ .12), while controlling for pleasantness/calmness before the task, condition, and income. Adding interaction terms of condition and fixation time indices also did not reveal significant effects (all *p*s ≥ .12).

4. Discussion

The current study examined how pro-environmental orientation and stress predict attentional engagement with visual representations of climate change. As for pro-environmental orientation, we found that HP compared to LP participants spent more time attending to both climate change and negative control pictures. Furthermore, acute stress reduced the amount of time participants spent looking at climate change and negative control images, irrespective of their pro-environmental orientation. The direct comparison between climate change and negative control images revealed that climate change pictures were on average fixated for a longer time than negative control pictures.

4.1 Effects of pro-environmental orientation

The finding that HP compared to LP participants looked more at climate change, but also at other negative images suggests that highly pro-environmental individuals are characterized by a generally increased willingness to attend to negative information. This result might reflect a stronger engagement with problems that are not immediately relevant, such as climate change or the suffering of strangers (negative control images), which would be in line with findings of increased self-transcendent values (Nordlund & Garvill, 2002; Schultz et al., 2005), prosocial values and behavior (Cameron et al., 1998; Kaiser & Byrka, 2011), and future orientation (Corral-Verdugo & Pinheiro, 2006; Ebreo & Vining, 2001) in pro-environmental individuals. Our result might also indicate a general attention bias towards negative stimuli as associated with the personality trait neuroticism, which has previously been found to correlate with pro-environmental orientation (Hirsh, 2010; Wiseman & Bogner, 2003). It could even be argued that a basic propensity to attend to negative information might be a cause rather than just the consequence of pro-environmental orientation, with increased attention to negative climate-related information leading to increased problem awareness, and, in turn, higher levels of pro-environmental attitudes and behaviors. Indeed, problem awareness is an important predictor and a necessary, albeit not sufficient, precondition of pro-environmental behavior (Bamberg & Möser, 2007; Nordlund & Garvill, 2002, 2003; Stern, 2000). Raising problem awareness can accordingly increase behavioral intentions, as demonstrated by a recent advertising study in which the presentation of threatening climate change images significantly increased cognitive threat beliefs, fear arousal, and pro-environmental intentions (Hartmann, Apaolaza, D'Souza, Barrutia, & Echebarria, 2014). Similarly, it has been shown that movie clips about global warming elicited negative emotions and increased the motivation to do something about climate change (Beattie, Sale, & Mcguire, 2011). Further research is therefore required to examine how LP individuals could be motivated to attend more frequently to information about climate change and how such increased attention might affect their intentional climate-friendly behavior.

4.2 Effects of stress

Our second finding of a negative effect of stress on the willingness to attend to climate change pictures is in line with previous propositions that individuals care more for environmental problems when they are not concerned with more immediate personal issues (Borden & Francis, 1978; Geller, 1995; Kollmuss & Agyeman, 2002; Sollberger et al., 2016). Similarly, the observed decrease in attention to negative control images might reflect diminished empathy for the problems of other people under stress (see e.g., Buruck, Wendsche, Melzer, Strobel, & Dörfel, 2014; Starcke et al., 2011; Tomova, von Dawans, Heinrichs, Silani, & Lamm, 2014).

Alternatively, or additionally, these negative effects of stress on eye movements towards negative images might reflect selective attentional deployment as an emotion regulation strategy (see e.g., Gross, 2014; Koole, 2009; Todd et al., 2012). That is, stressed individuals might have selectively directed their attention away from negative images to counteract the maintenance or intensification of stress-induced negative emotions. This interpretation would be consistent with several previous studies that have observed avoidance of negative information under conditions of induced stress or negative mood (Ellenbogen et al., 2002; Isaacowitz et al., 2008; Newman & Sears, 2015; von Ceumern-Lindenstjerna et al., 2010). Importantly, in the present study stress did not interact with pro-environmental orientation, indicating stress-induced gaze aversion from negative pictures in HP as well as LP participants.

The current findings do not allow for conclusions regarding the biological mechanisms of the observed stress effect on attentional deployment. Gaze direction was not associated with cortisol response, arguing against exclusive mediation by cortisol. Considering that the eye-tracking task took place directly after the stress induction and thus during the peak of the cortisol response, it also remains unclear whether the cortisol response itself may have been affected by the picture viewing task as a whole. Further research should consider other biological stress markers, for example indicators of the fast-responding sympathetic-adrenal-medullary system, such as catecholamines or salivary alpha amylase. It would also be insightful to investigate time-dependent effects of stress on attentional deployment by varying the timing of the attention task following stress induction.

As for associations between gaze behavior and mood, fixation time on negative images did not predict mood changes, suggesting that gaze aversion from negative pictures was not accompanied by a mood increase. This does, however, not preclude that negative images were avoided based on the (implicit or explicit) motivation to regulate emotions, since the presence of such a motivation does not yet guarantee actual success of respective strategies. Also, it is possible that the employed mood measures were not sensitive enough to capture gaze-induced mood changes. Particularly, in the stress group mood generally improved substantially during the eye-tracking task following completion of the TSST (see Figure 3), which may have masked smaller mood changes due to differences in gaze behavior. Future studies might attempt to implement measures of current motivation or intention for emotion regulation to more directly assess underlying motivational mechanisms of stress effects on attentional deployment.

In contrast to some previous studies using sad mood induction paradigms (Isaacowitz et al., 2008; Newman & Sears, 2015; Sanchez et al., 2014), we did not find increased attention to positive images after acute stress. It therefore appears that the TSST did not specifically activate the emotion regulation strategy of attending to positive information.

4.3 Implications

A further aim of the present study was to compare attention allocation to climate change images with attention to other negative images presented under similar conditions (i.e., in the presence of positive and neutral distractors). Notably, climate change images were attended for a longer time than negative control images and were indeed the most attended category within climate trials. This result indicates that visual representations of climate change are able to arouse and maintain interest for a prolonged period of time in the presence of competing stimuli, which, in itself, is an interesting and promising result. Together with the observed evidence for an avoidance of climate change information under stress, these findings may have important implications for the design and planning of green advertising campaigns. In particular, the present results suggest that individuals are generally interested in depictions of the climate problem, but less willing to attend to it when they are confronted with more immediate concerns such as acute stress. Stress is a common part of everyday life and thus potentially affects our attention and gaze behavior on numerous occasions. At the same time, stress is more temporary and easier to influence than other potential predictors of attentional engagement with climate change (e.g., demographic factors, traits). Climate change awareness campaigns might therefore benefit from specifically targeting individuals in a relaxed and unpreoccupied state, for example by approaching them in a stress-free context. Furthermore, it would be interesting to examine whether attentional engagement with climate change can be favorably influenced by interventions specifically designed to reduce stress, such as stress prevention and management programs.

4.4 Limitations and future directions

The current research has some limitations that should be noted. First, the homogenous study sample included only male participants under the age of 40 with either low or high pro-environmental orientation. Further research is thus needed to examine whether the present results generalize to female and older populations, especially since previous research has reported gender and age effects on pro-environmental behavior, with females (Diamantopoulos, Schlegelmilch, Sinkovics, & Bohlen, 2003; Hunter, Hatch, & Johnson, 2004; Thøgersen & Ölander, 2006; Zelezny, Chua, & Aldrich, 2000) and older people (European Commission, 2008, 2009; Grønhøj & Thøgersen, 2009; Swami, Chamorro-Premuzic, Snelgar, & Furnham, 2011) tending to show higher levels of pro-environmental behavior. Furthermore, the climate-related gaze behavior of individuals with intermediate levels of pro-environmental attitudes and behaviors should be investigated. Also, the final sample sizes of the four experimental groups were relatively small, which may have limited the likelihood of discovering potential interaction effects of pro-environmental orientation and stress. Future research might benefit from investigating climate change related gaze behavior in real-world settings, where subjects' choice of attentional focus is less limited by the experimental paradigm, for example by using mobile eye-tracking. It would also be interesting to study participants' gaze behavior in response to pictures associated with climate change mitigation (e.g., renewable energy technologies). In a next step, it might also be examined how attentional engagement with climate change affects intentional climate-friendly behavior and how selective attention to the global warming problem might be specifically increased.

4.5 Conclusion

To sum up, the presented results suggest that attention allocation to climate change images can be predicted by trait and state factors in a similar way as attention to other negative images. While pro-environmental orientation has a positive effect on participants' willingness to attend to climate change and other negative pictures, acute stress reduces attentional deployment to these image categories. Overall, our findings provide first evidence for important determinants of attentional engagement with climate change as a precondition of intentional climate-friendly behavior.

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Highlights

- High pro-environmental orientation increases attention to climate change images
- Experimentally induced stress decreases attention to climate change images
- Both effects generalize to other negative images (social scenes)
- Climate change images attract more attention than other negative images